Comparison of Simultaneously Recorded Computerized Occlusal Analysis and Surface Electromyographic Activity of Masticatory Muscles Between Patients with Unilateral TMD

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Submitted February 25, 2020; accepted June 19, 2020

Abstract

Purpose: To investigate the relationships among occlusion time, disclusion time, occlusal load distributions, and simultaneous electromyographic (EMG) recordings of the anterior temporalis (TA) and masseter (MM) muscles
during centric and lateral movements in patients with unilateral temporomandibular disorder (TMD) pain and in asymptomatic control subjects. **Materials and Methods:** Twelve healthy and 13 unilateral TMD subjects participated in the present study. The diagnosis of unilateral TMD was verified with vibrational analysis of the temporomandibular joints (TMJs) using the BioJVA (BioResearch Associates). Simultaneous computerized digital occlusal analysis using T-Scan III (Tekscan) and EMG activity of the MM and TA muscles using BioEMG III (BioResearch Associates) were performed in the intercuspal position and in right and left excursive movements. In intercuspal and lateral movement records, EMG activity of the masticatory muscles, occlusion time, disclusion time, and bite force distribution ratios were evaluated. **Results:** No statistically significant differences were observed in occlusion time, disclusion time, or EMG activity of the MM and TA muscles between controls and patients with unilateral TMD in the intercuspal position. In unilateral TMD patients, disclusion time of the painful side was significantly higher than in the control group and compared to the nonpainful side ($P < .05$). Bite force distribution of the balancing side in TMD patients was shown to be statistically significantly higher values than in control subjects. EMG activity of the working-side TA muscle was higher than the nonworking side TA in controls and in the nonpainful side of TMD patients ($P < .05$). However, EMG activity of both the MM and TA muscles did not show a difference between the working side and nonworking side in unilateral TMD patients. **Conclusion:** In the intercuspal position, there was no difference in occlusion time, distribution of force, or EMG activity of the masticatory muscles observed between the control group and unilateral TMD pain patients. However, in lateral movements, the painful side of the unilateral TMD patients revealed increased balancing side TA activity, with higher disclusion time and balancing side force distribution. *Int J Prosthodont* 2021. doi: 10.11607/ijp.6935

**Introduction**

Temporomandibular disorders (TMD) is defined as functional disturbances of the masticatory system leading to pain and dysfunction in temporomandibular joint, muscles of masticatory system, and related structures. TMD is a multifactorial disorder that the numbers of aetiologic agents are attributed to the origin of TMD. The important issue to be considered is that one of the etiologic factors associated with TMD is the occlusal condition of the patient. In many researches, occlusion have been evaluated as an initiative factor of TMD that malocclusion, extreme maxillary overjet, crossbite, asymmetry of occlusal contacts, occlusal instability, occlusal interferences have been related to TMD. On the other hand, although the presence of a
possible relationship between occlusion and the aetiology of TMD, there is a debate and controversial aspects about the relationship between TMD and occlusion in dental community.

Conventional occlusal analysis systems usually use, such as inked silk, articulating paper, or plastic. However, they cannot measure the surface area of contacts, amount of force, and contacting time sequence. Also, these equipments are far from the optimal occlusal analyser due to their static nature and subjective evaluating feature. Moreover, there is not sufficient literature evidence related to their reliability and reproducibility. T-Scan occlusal analysis systems manufactured by Tekscan to come through these restrictions. The computerized occlusal analysis system records the occlusal contacts from the first point to maximum intercuspation in real-time and can quantify occlusal contacts timing and forces.

T-Scan occlusal analysis system provides evaluation occlusion time (OT), disclusion time (DT), and distribution of occlusal forces in the dental arch. Occlusion time is defined as the time period from the first contact to maximum intercuspation and ensure determination of too early tooth contacts absorbing excessive early occlusal stress, or too late contacts being unable to assist in closure and occlusal force dissipation. Whereas, disclusion time is defined as the required time from maximum intercuspation to complete disocclusion of all molars and premolars during lateral movements. It has been stated that occlusion time can be considered as a description of occlusal features, whereas disclusion time could be related to effect of tooth contacts on muscle activity, and extended DT would result in extending of muscle activity, thus facilitating the onset of TMD. In electromyographic (EMG) studies, lengthy disclusion time was shown to increase the contractile activity of masseter and temporalis muscles, and that proper reduction of the disclusion time to <0.4 s have been suggested to reduce the muscle hyperactivity and related myofascial pain symptoms. According to the manufacturer, occlusion time is recommended as less than 0.2 s, and disclusion time less than 0.4 s. However, in the literature, there have been stated various OT and DT times that was outside of the known physiological ranges. Furthermore, there is no clarity about the difference in OT and DT value between healthy and TMDs patients.

Recently, two different technologies have been synchronized together: T-Scan III and BioEMG III (T-Scan/BioEMG linking software, Tekscan Inc/Bioresearch Associates technology partnership). They simultaneously record changing in EMG activity levels and occlusal contact force data with high definition. The simultaneous recording allows clinicians to analyse and correlate specific occlusal contact to specific electromyographic changes that result from this occlusal contacts. With this combined system, occlusal analysis and EMG activity can be recorded and played back simultaneously for further analysis. TMD most
often manifest with a muscular abnormality and changes in electromyographic activity of masticatory muscles in TMD patients.\textsuperscript{17} However, there have been limited studies evaluating the effect of simultaneous recordings of functional occlusal conditions on the EMG activity of masticatory muscles in healthy and TMD patients.

The pain in patients with TMD is more usually unilateral rather than bilateral.\textsuperscript{18} Therefore, the changes in occlusion and the muscle activity could only occur in the painful side or whether they also occur bilaterally. In accordance with these hypotheses, unilateral temporomandibular disorders have been associated with the asymmetry in the number of occlusal contacts.\textsuperscript{19} Another study, EMG activity of masticatory muscles in pain side of unilateral TMD patients revealed lower values than non-pain side.\textsuperscript{20}

Therefore, the present study aimed to investigate the relationships occlusion time, disclusion time, occlusal load distributions and simultaneous EMG recordings of TA and MM muscle during intercuspal position and lateral movements in patients with unilateral TMD and asymptomatic control subjects.

**Materials and Methods**

**Participated Subjects**

Twelve healthy subjects and 13 patients with unilateral temporomandibular disorders pain between 18 and 40 years old were selected from Department of Prosthodontics Clinics. The study was approved by the Ethics Committee at Gazi University, Faculty of Dentistry (03/2017-11). All subjects participated voluntarily to the present study and obtained written informed consent form, according to the ethical guidelines recommended by the Helsinki Declaration. The inclusion criteria were no systemic disease, no craniofacial trauma or surgery, no using any medication, no reported sign and symptoms of TMD, full permanent dentition (not including third molars), no history of TMD treatment. A history and clinical examination were performed for all participated subjects using the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) Axis I \textsuperscript{21}. The diagnosis of unilateral TMD was verified with the vibrational analysis of the temporomandibular joints (TMJ) using the BioJVA (Bio Research Associates, Inc. Milwaukee, WI, USA). Before BioJVA analysis, all patients were informed about the process. Patients were positioned in resting position, sat upright and looked straight ahead. Maximum mouth opening (including overbite) was measured with a ruler and then it was registered into the program. The vibraphone parts of the device were placed on both joints, and the patient was instructed to open and close the mouth as much as possible. The movements were guided by an arrow in the metronome on the computer screen. Recording of the right and left TMJ vibrations was drawn on the computer screen in real time. In ten seconds, subjects were performed six times complete opening and closing cycle of the mouth and
data were registered. Then, the summary of registered joint vibrations was analysed and the amount of the vibration energy in each TMJ were calculated. The diagnosis made with BioJVA according to Piper classification that was based on MRI (Magnetic Resonance Imaging) findings. The analysed temporomandibular joints were divided into 5 groups with several subcategories. A Piper I classification indicates that the disc is normal, Piper II indicates that the disc is in a normal position, but the ligaments are stretched, Piper III indicates that the disc is partially displaced, Piper IV indicates that the disc is completely displaced, Piper V indicates that there is no longer any tissue between the condyle and the eminence. All unilateral TMD patients who participated to present study were classified as internal derangement of TMJ.

**Recording devices**

The computerized digital occlusal analysis was performed with T-Scan III (Software version 9.1, Tekscan Inc., South Boston, MA, USA). The appropriate size sensors and holder were attached to the handle, which is connected to the computer. The recordings were made in Turbo mode. Central incisor width was measured in order to determine the dental arch width in T-Scan software. Sensor sensitivity adjustments were performed in order to fit the individual’s force level using Sensitivity Wizard. That adjusts the sensor’s output with the biting force of the patients.

Also, the EMG activity of masseter and anterior temporalis muscles were recorded with Bio EMG III (BioPAK, Bioresearch Associates Inc., Milwaukee, WI, USA). Before recordings, patients' skin was cleansed with 95% alcohol. Self-adhesive bipolar EMG surface electrodes (Bioflex, Bioresearch Associates, Inc., Milwaukee, WI, USA) were positioned bilaterally on the bodies of muscles and parallel to the direction of muscle fibers. The reference ground electrode was placed on the neck. All EMG data were recorded through a Bio EMG III amplifier and the BIOPAK computer program.

**Examination Procedure**

The subjects were seated in upright position with the parallel to the Frankfurt horizontale plane. Simultaneous digital computerized occlusal analysis and EMG activities of MM and TA muscles were performed in intercuspal position and lateral movements (right and left movements). In intercuspal position, the patient repeats 3 clenches on their posterior teeth for 1-3 seconds, and the occlusion and EMG activity of masticatory muscles were analysed. In all excursive movements, patient occludes in intercuspal position for 1-3 seconds and then slide the mandibula to right or left.
In records of the intercuspal position, EMG activities of MM and TA muscles, occlusion time and distribution of bite force have been analyzed. In records of excursive movements: simultaneous EMG activity of MM and TA were evaluated with disclosure time and distribution of bite force. Occlusal parameters have been analysed according to the following descriptions. Occlusion time; has been defined as the time from the first contact of tooth to maximal intercuspation, Disclusion Time; the time required for completely disocclude of posterior teeth in a mandibular excursion, Left-right distribution of bite force ratios: force balance between the two halves of the dental arch.

Statistical analysis

All data were analysed using the Statistical Package for the Social Sciences version 16.0 (SPSS Inc., Chicago, IL, USA) with a 5% significance level. First, Kolmogorov-Smirnov tests were used to evaluate the normal distribution, and all data were normally distributed. In the comparison of disclusion time, Bite-Force distribution, EMG activity of MM and TA in intercuspal position and lateral movements were analysed. One-way ANOVA analysis was performed to the comparison between the control group and each side of the unilateral TMD pain patients. Evaluation of occlusal parameters and EMG activities between subgroups (right-left comparison for Control group, and pain and non-pain side comparison for Unilateral TMD patients) were analysed with independent sample t-test.

Results

Intercuspal position

No statistically significant differences were observed in occlusion time between the control and unilateral TMD pain patient group (Tabel 1) (p > 0.05). Distribution of bite force and EMG activities of MM and TA muscles were revealed no statistically significant difference between the left and right side in the control group and between the pain and non-pain side in the unilateral TMD pain patients group (Table 2) (p > 0.05).

Laterotrusive Movement

In unilateral TMD pain patients, disclusion time of pain-side was significantly indicated the higher value than the non-pain side (p<0.05) and control group (Tabel 3). In control subjects right and left disclusion time did not show any significant differences.
Biting force distribution of all control, pain-side, and non-pain-side of TMD patient groups were revealed the higher values in the working side than balancing side ($p<0.05$). However, bite force distribution of balancing-side in pain side-TMD patients was showed statistically significant higher values than that of control subjects ($p<0.05$). However, there was no statistically significant difference in balancing side bite force distribution between pain and non-pain side of TMD patients.

EMG activities of working-side TA muscle was higher than non-working side TA, and nonworking side MM muscle showed higher EMG activities than working-side MM muscle ($p<0.05$) in control subjects. In the non-pain side of TMD patients, there was no statistically significant difference in EMG activity of MM between working and non-working side. However, working-side TA muscles activities were higher than those of the non-working-side TA muscle activities. EMG activities of both MM and TA muscles did not show the difference between the working side and non-working side in pain side of TMD patients.

**Discussion**

In the present study, all subjects underwent Joint Vibration Analysis (JVA) to verify the condition of the temporomandibular disorder that unilateral internal derangement patients were included. The vibration analysis of the TMJ quantitatively evaluates the absolute intensity and frequency distribution of vibratory waves in the joints during jaw movements. It is a precise, quick, non-invasive, device that objectively records all the vibrations of the underlying tissue during function, distinguishes which side the vibration originates on, creates a visual image of the vibration and measures its intensity. There are many studies showing that a reliable clinical diagnosis can be made analysing TMJ vibration energy parameters recorded by BioJVA. In addition, it provides a proper distinction between patients with normal joint anatomy and internal derangement. Because of these reasons, we used BioJVA method in diagnosis of subjects.

In many studies, occlusion has been related to the aetiology of TMD. However, current studies related to the occlusion of TMD subjects have shown variance in respect to the use of different materials and recording methods. Furthermore, inhomogeneity of TMD patients may be an additional reason for the different result. In the present study, the T-Scan occlusal analysis system has been used to analyse occlusion that record occlusal contacts quantitatively with force and time sequencing and dynamically during continuous mandibular movements.

Results of the present study did not indicate any differences in occlusion and disclusion time between TMD and control subjects in the intercuspal position. Occlusion time is related to premature contacts and
occlusal stability. Destabilization of occlusion has been evaluated as a factor to be considered that may cause occluso-muscle disorders.\textsuperscript{29} Also, premature occlusal contacts have been related with condyle displacement that potentially cause friction and increased intra-articular pressure on the TMJ and, thereby contribute to the onset of TMD.\textsuperscript{30} Kerstein et al. suggested the $<0.2$ s for ideal occlusion time.\textsuperscript{14-16} However, in the present study, occlusion time was varied to 0.48 s for TMD and 0.45 s for the control group and did not show any significant differences. These results were in accordance with the result of studies carried by Baldini and Nota found no difference in occlusion time between TMD and control subjects.\textsuperscript{31}

On the other hand, in both of TMD and control subjects, occlusal force distribution did not show any difference between both sides (left/right for the control group, pain and non-pain side for TMD group). Occlusal force distribution is related to the occlusal balance status and balance of the masticatory muscles. Compatible with the EMG result, there was no asymmetric relation in masticatory muscle activities (MM and TA) and distribution of bite force between left-right side for the control group and, pain and non-pain side of unilateral TMD patients.

TMD is known to cause significant changes in the electrical activity of masticatory muscles due to the nature of the disorder or compensatory mechanisms that have seen as a result of the symptoms.\textsuperscript{32} In many studies, lower EMG activity of TMD patients with pain than healthy subjects have been stated.\textsuperscript{33} In an experimental study with TMD patients performed by Mapelli et al. presence of pain produces decreased EMG activity not only in painful muscles but also non-painfull muscles.\textsuperscript{34} According to the present result in MVC (Maximum Voluntary Contraction), in both pain and non-pain side of unilateral TMD patients revealed lower EMG activity of MM and TA than healthy subjects; however, these difference was not statistically significant. It could be related to the severity of pain intensity of unilateral TMD patients or contribution of unilateral TMD patients. Because it has been stated that bilateral TMD pain shows more reduced EMG activity than unilateral TMD patients.\textsuperscript{35}

One of the other aims of the present study was to evaluate the effect of dynamic occlusal parameters on the set of TMDs. In lateral movements: disclusion time, working and balancing occlusal force distribution and EMG activities of MM and TA muscles during these movements were evaluated. It has been stated that prolonged disclusion time leads to increased EMG activity of masticatory muscles and stress on the articular disc that can facilitate the occurrence of TMD symptoms.\textsuperscript{28} As well Kerstein suggested that proper reduction of the disclusion time to $<0.4$ s can reduce the hyperactivity of muscles and related myofascial pain symptoms.\textsuperscript{11} In the
comparison of right and left disclusion time in control subjects did not show any difference, however, disclusion time in pain side of TMD patients have shown a higher value than control and non-pain side of TMD patients. Present result was an agreement with many studies that found extended disclusion time in TMD patients.36-38

In the comparison of the distribution of force in lateral movements, the ratio of non-balancing side contacts had higher percentage value in pain-side of unilateral TMD patients than non-pain-side of unilateral TMD patients and control subjects. In a recent study, non-functional tooth contacts have been related to TMD that patients with TMD have about 3.6 times more frequent non-functional tooth contacts.39 In many studies, mediotrusive interferences have been found related to signs and symptoms of TMD.40,41 And, the elimination of such interferences was also suggested.41 Okeson claimed that interferences could have harmful effects on masticatory muscles; in particular, chronic interferences could lead to progressive and non-symptomatic adaptation.42

With the synchronization of the BioEMG 3 and T-Scan 3 systems, force and time sequencing were recorded on a force-movie graph that can be time-correlated to specific changes in muscle activity levels.16 In the healthy and non-pain side of unilateral TMD subjects, during lateral movements, working-side EMG activity of TA muscles had shown higher values than those of the balancing side, and balancing side EMG activity of MM was higher than those of the working side. The dominance of TA activity on the working side has been stated by Hugger et al. and Okan et al., too. However, in the pain side of the unilateral TMD patients, there was no significant difference between working and balancing side EMG activity in TA muscles. MM and TA muscles exhibit largely uniform bilateral activity in lateral positions.43,44 These results showed accordance with the results of Li et al. study.45 The more balancing side contact and/or prolonged disclusion time of pain side of unilateral TMD patients increased EMG activity of balancing TA muscle and to changes of TA muscle EMG activity from an unilateral to a symmetrical pattern.

Conclusions

The patients with unilateral TMD pain showed no pain side associated changes in occlusion time, distribution of force, and EMG activity of masticatory muscles in the intercuspal position. However, in lateral movements, dominance TA activity in working side of control group changed to symmetrical pattern with increased balancing side TA activity in pain side of unilateral TMD pain patients, as a result of the higher disclusion time and balancing side distribution force in the pain-side unilateral TMD patients. As a summary in
clinical examination, increased TA activity and occlusal contact changes in non-pain side should be considered in patient with unilateral TMD patient.

Acknowledgement

Present study was supported by Gazi University Scientific Research Projects (BAP), (Project number:03/2017-11).

References


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Tables

Table 1. Occlusion time in control subjects and unilateral TMD pain patients in intercuspidation

<table>
<thead>
<tr>
<th>Occlusion time (s)</th>
<th>Unilateral TMD pain group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.48</td>
<td>0.45</td>
</tr>
<tr>
<td>P value</td>
<td>0.87</td>
<td></td>
</tr>
</tbody>
</table>

*Independent sample t test, p<0.05

Table 2. EMG activities of MM and TA, distribution of bite force in control subjects and Unilateral TMD pain patients in intercuspidation

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Unilateral TMD pain group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right side</td>
</tr>
<tr>
<td>Emg activity of MM (Mpa)</td>
<td>Mean</td>
</tr>
<tr>
<td>131,23</td>
<td>126,46</td>
</tr>
<tr>
<td>TA (Mpa)</td>
<td>156,19</td>
</tr>
<tr>
<td>Distribution of bite force (%)</td>
<td>52,075</td>
</tr>
</tbody>
</table>

*Independent sample t test, p<0.05

EMG: Electromyography, MM: Massater Muscle, TA: Temporalis Anterior Muscle, TMD: Temporomandibular disorders
Table 3. EMG activities of MM and TA, distribution of bite force and disclusion time in control subjects, pain and non-pain side of unilateral TMD pain patients in lateral movements

<table>
<thead>
<tr>
<th></th>
<th>Control group</th>
<th>Pain side unilateral TMD group</th>
<th>Non-pain side unilateral TMD group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
</tr>
<tr>
<td>Distribution of bite force (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working side</td>
<td>92,48&lt;sup&gt;A,H&lt;/sup&gt;</td>
<td>74,38&lt;sup&gt;A,I&lt;/sup&gt;</td>
<td>85,54&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Non-working side</td>
<td>7,51&lt;sup&gt;B,H&lt;/sup&gt;</td>
<td>22,1&lt;sup&gt;B,I&lt;/sup&gt;</td>
<td>17,96&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>EMG activity of working side (Mpa)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MM</td>
<td>55,78</td>
<td>36,75</td>
<td>39</td>
</tr>
<tr>
<td>TA</td>
<td>60,89&lt;sup&gt;G&lt;/sup&gt;</td>
<td>44,52</td>
<td>51,7&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>EMG activity of non-working side (Mpa)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MM</td>
<td>61,29&lt;sup&gt;*&lt;/sup&gt;</td>
<td>38,99</td>
<td>34,20&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
<tr>
<td>TA</td>
<td>28&lt;sup&gt;G&lt;/sup&gt;</td>
<td>34,87</td>
<td>27,2&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Disclusion time (s)</td>
<td>0,61&lt;sup&gt;D&lt;/sup&gt;</td>
<td>0,84&lt;sup&gt;D,E&lt;/sup&gt;</td>
<td>0,63&lt;sup&gt;E&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

*Same superscript letters indicate statistically significant difference.

EMG: Electromyography, MM: Masseter Muscle, TA: Temporalis Anterior Muscle, TMD: Temporomandibular disorders

Oneway ANOVA, p<0.05